V.P.

NASA TECHNICAL TRANSLATION

NASA TT F-14,976

SMALL-SCALE GEOBOTANICAL ZONING AND CARTOGRAPHY BASED ON SPACE PHOTOGRAPHY OF THE EARTH

B. V. Vinogradov

(NASA-TT-F-14976) SMALL-SCALE GEOBOTANICAL ZONING AND CARTOGRAPHY BASED ON SPACE PHOTOGRAPHY OF THE EARTH (Scripta Technica, Inc.) 25 p HC $3.25 CSCL 08B G3/13

N73-26392

Unclas 08710

Translation of: "Melkomasshtabnoye Geobotanicheskoye Rayonirovaniye i Kartirovaniye po Kosmicheskim Izobrakheniyam zemli," in: Geobotanicheskoye Kartografirovaniye, Academy of Sciences of the USSR, Komarov Botanical Institute, 1970, "Nauka" Press, 1971, pp. 3-18.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 JULY 1973

25

STANDARD TITLE PAGE

1. Report No. NASA TT F-14,976	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SMALL-SCALE GEOBOTANICAL ZONING AND CARTOGRAPHY BASED ON SPACE PHOTOGRAPHY OF THE EARTH		5. Report Date JULY 1973
		6. Performing Organization Code
7. Author(s) B. V. Vinogradov		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Scripta Technica, Inc.		11. Contract or Grant No. NASw-2484
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: "Melkomasshtabnoye Geobotanicheskoye Rayonirovaniye i Kartirovaniye po Kosmicheskim Izobrakheniyam zemli," in: Geobotanicheskoye Kartografirovaniye, Academy of Sciences of the USSR, Komarov Botanical Institute, 1970, "Nauka" Press, 1971, pp. 3-18.

16. Abstract

Space photography is discussed as a new and prospective science for use in geobotanical mapping. Emphasis is placed on the fact that this field has received little study. Using predominantly American data, several examples of geobotanical mapping are provided, with an interpretation.

17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 25	22. Price 3.25

NASA TT F-14,976

SMALL-SCALE GEOBOTANICAL ZONING AND CARTOGRAPHY BASED ON SPACE PHOTOGRAPHY OF THE EARTH

B. V. Vinogradov

Today, methods of interpreting space photographs of the Earth in meteorology and oceanology are comparatively well studied; here these have already found practical application. Questions of interpreting space photographs in other Earth sciences have begun to be developed: geology, geomorphology, geobotany, etc. /3*

Certain reports on the photointerpretation of vegetation are contained in studies devoted to the application of space photography in geographic investigations (Bird, Morrison, 1964; Lowman, 1965; Lowman, To Lou Chang, 1965; Vinogradov, 1966a, 1969), and there are indications of the possibility of using space photography during phenological observations (Conover, 1965), and during the study of forests (Wilson, 1967). In a number of publications, the operating perspectives of the orbital space laboratory in the field of studying natural resources are discussed, this includes vegetation (Garrison et al., 1965; Badgley, Vest, 1966; Colwell, 1967; Park, 1968; Waltz, 1968; Vinogradov, Kondrat'yev, Stepanenko, 1968).

The photographs of the Earth obtained from space can be divided into 2 basic groups: 1) original photographs taken from automatic and manned spacecraft (SC), delivered to the Earth in containers, 2) television images of the Earth's surface transmitted to the Earth from artificial satellites of the Earth (ASE) along television channels.

Photography of the Earth's surface is carried out by cosmonauts or automatic small cameras (from 6 X 6 cm to 16 X 20 mm) using panchromatic and color films. The orbital altitude of the spacecraft, from which photography is carried out with return of the negatives to the Earth, as a rule, is comparatively low — up to 300-400 km. The scales of the original photographs

*Numbers in the margin indicate pagination in the foreign text.

fluctuate nearly 1:5 X 10^5-1:10^7 with significant terrestrial resolution which reaches 50 m, and in rare cases differentiated photographs yield even smaller details.

Television photography of the Earth has a certain advantage over actual photography from spacecraft in frequency, repetition, and regularity of obtaining photographs of the Earth's surface. Existing systems of artificial satellites of the Earth transmit television imagery of practically the entire (or nearly the entire) surface of the Earth in the course of one calendar day. Television photography is carried out, as a rule, from artificial satellites /4 of the Earth which are located in higher orbits — 1,000-1,500 km and more. They transmit original imagery into scales 1:5 X 10^6-1:5 X 10^7. Terrestrial resolution of the received television images is 500-3,000 m, but there are realistic possibilities of increasing their terrestrial resolution to 100-200 m.

The basic method of interpreting space photographs (which is the same as the earlier developed method of decoding aerial photographs) is a method of combined decoding based upon obtaining selective information of key regions and extrapolating data on the photographic image beyond the limits of these regions. Here, in the process of interpreting super small scale space photographs, in addition to recognition points of terrestrial field observations, local geobotanic descriptions, maps, and interpreted aerial photographs of moderate and small scale can also be used. During this process, for interpreting the space photographs, special maps must be used in the key regions whose scale is from 2 to 4 times larger than the scale of the space photographs, inasmuch as the information of the latter is significantly more detailed than the special maps of the same scale.

At the first stage of the investigation we do not set as our task recognition of vegetation for revealing new characteristics of the structure of the vegetative cover. Today, in the complete absence of experience in interpreting vegetation according to space photography, the basic tasks are those of detecting the decoding signs of mega-, macro- and sometimes mesocombinations[1] of plant communities, establishing the possibility of interpreting vegetative and ecological conditions according to super small scale photographs, and determining the principles of photographs of vegetation during photography of the Earth from space.

The principles of optic and geometric generalization of photographs of the plant cover in super small scale space photography is as yet nearly unstudied. A number of observations, however, indicate that in the space photograph large differences in types of vegetation and ecological conditions are delineated, while at the same time one interprets finer details.

The optic generalization consists in the fact that objects having differing coefficients of spectral brightness yield integral coefficients of brightness of the totality of objects, which frequently leads to a decrease in contrasts. However, from the viewpoint of cartography we are primarily interested in geometric generalization, which consists in integrating fine objects with differentiated photographs on ordinary aerial photographs in contours with integral imagery on the space photographs.

On space photographs of the usual scales (nearly $1:10^6$), contrast details having a dimension of to 20-50 m are depicted, while low contrast contours of up to 100-200 m are also depicted. This enables one to compare space photographs[2] scale $1:10^6$ with respect to the detailed nature of the information (proceeding from the size of the smallest contour of a map 2 mm^2) with maps of a scale 1 order larger ($1:10^5$). The possibilities for increasing terrestrial resolution of space photographs are great, and with the use of the appropriate apparatus, according to the data of American authors (Bird, /5

[1]Mezocombinations of plant communities correspond to the vegetation of naturally defined areas, macrocombinations — the vegetation of regions, megacombinations — the vegetation of districts having a size defined in concepts cited by us earlier (Vinogradov, 1966b).
[2]In indicating the scales of space photographs being interpreted, one has in mind an increase of 2.5 to 4 times in printing from the original space photographs and television images having a scanning field of nearly 5 lines per mm.

Morrison; Badgley, Vest, 1966), the recognition of adequate contrast details can be taken to 5-10 m.

The solution of problems of generalization can make possible the comparison of medium and large scale aerial photographs with super small scale space photographs of the same territories. We shall examine this using the example of the mountains of Old Baldy, Arizona, whose altitude reaches 2,874 m above sea level (Shreve, 1922; Daubenmire, 1943; Wilson, 1967). These mountains are located in a semiarid region and the lower slopes are covered by communities of formations of xerophyte undergrowth (*Larrea tridentata* Coville) and grasses (*Bouteloua eriopoda* Torr. etc.). In ordinary aerial photographs having a scale of nearly $1:2 \times 10^4$, this surface is depicted by grey and light grey shades with a complex picture of interlaced channels of the flow of wash-waters, having in places groups of small foci of undergrowth. On space photographs, thin vegetation of this character is depicted by shades of a grey tone. It has practically no influence on the shades of the image, and the latter is basically determined by the optical characteristics of the surface Quaternary deposits and rocks.

Higher along the slopes there is a combination of similar semiarid land with juniper (*Juniperus utahensis* Lemm.) — pines (*Pinus edulis* Engelm.), and thin forests which are encountered along the valleys and northern slopes under favorable ecological conditions and which occupy no more than 30% of the total area. In the ordinary medium scale aerial photographs, this belt is depicted by a contrast combination of semiarid slopes of an even grey, light--grey shade and a band of wooded, undergrowth vegetation of a darkish-grey and dark-grey shade with a granular texture along the ravines and northern slopes. On the space photographs this combination is integrated with a darkish-grey shade which is poorly distinguishable from the semiarid territories. In places one notes a striated texture which is caused by the influence of shadows of the steep slopes of the erosive gashes and a belt of wooded-undergrowth vegetation which has been confined to the valleys.

On the midway levels of the slopes of the mountains, a pine-juniper thin forest occupies more than 60% of the area and forms extremely low (less than 10 m in height) and thin (up to 0.6 degree of closeness) vegetative cover.

In the aerial photographs these are depicted by darkish-grey, dark (dependent upon exposure) shade with a coarsed grain nondense texture and in places one can see a light-grey topsoil cover. In the space photographs, these thin forested areas are defined by a dark-grey shade with a certain masking of the image of the erosion relief.

Finally, the upper level presents a picture of high and closely grown mixed forests of *Quercus undulata* Torr. and *Pinus ponderosa* Dougl. In the aerial photographs, the oak-pine forest is depicted by a uniform, moderately granular closely joined texture, in the midst of which one cannot usually see the topsoil covering. In space photography this level is set off by a monotone dark shade. Within its limits one practically does not note the spots of unforested slopes, changes in relief and forms of the hydrographic network.

A similar integration of the photographic imagery was observed by us during the transition from ordinary aerial photographs to space photography in the valley of the Rio Grande River (New Mexico, USA), the sands of Uarran (Mauritania) and a number of other territories.

A similar comparison is demonstrated, in space photographs not only separate communities yield integral imagery, but also mezocombinations (plant boundaries), while an integral shade in a space photograph is a mean resulting from the shades of individual communities proportional to the quantitative relationship of the /16
latter. A

Dependent upon the composition and density of vegetation, methods and signs for decoding territories according to space photographs change. One category of regions includes territories whose photographic image, at any rate in the summer, is almost entirely determined by the character of both natural and cultivated plants. This is a majority of the regions of humid zones and a number of regions and clearly bounded regions of the arid zones. In these regions, differences in the composition of vegetation confined to various geological, geomorphological, and hydrological conditions determine the specific characteristics of the photographic image of the latter. In such regions, vegetation can be used in the capacity of an indicator for drawing boundaries between types of geological deposits and for tracing geological structures.

In another category of regions — open regions — thin, xeromorphic vegetation can be interpreted according to indirect signs, primarily relief and geological structure. The shade of the image of open regions is determined by the broken nature of the surface, by the lithologic and mineralogical composition of the primary rock and by the surface Quarternary deposits, while in certain cases it is also determined by their moisture and salinization. Notwithstanding the fact that the broken nature of vegetation is not recognized according to direct signs and does not determine the actual character of the photographic image, it can be interpreted in space photographs according to complex signs, thanks to the regional method of decoding plant communities based on the utilization of interrelationships of plants and environmental factors.

Space photographs have properties of geographic integration: territorial, factoral, and dynamic (Vinogradov, 1966a).

Territorial integration is uniting various structures and combinations of vegetation of a high order in a single image, zones, belts, regions, mega- and macrocombinations.

Factor integration is uniting in a single image, in addition to vegetation, other components of the region: geological and geomorphological structure, hydrography, meteorological phenomena, elements of cultivation, agricultural and industrial regions.

One can also distinguish dynamic (and rhythmic) integration, which differs somewhat from the two preceding types; by dynamic integration we mean obtaining by means of a single photographic system, comparable photographs of the same territory at various hours of the day, in various seasons, in different years, which reflect daily, weather, seasonal, and multi-year rhythm and dynamics of vegetation.

For plant cartography all of the enumerated forms of integration are significant, however the most valuable is territorial integration. Below are cited examples of interpretation of the most large scale territorial units of vegetation according to super small scale space photographs of the Earth: 1) latitude zones, 2) altitude belt, 3) megacombinations (the vegetation of elementary regions or physical-geographical regions, 4) typological units.

Latitude zones of vegetation. Large botanical-geographic divisions — zones of vegetation — can be differentiated on the most small scale space photographs having a scale of $1:10^7$ and smaller, and governed by the changes in predominant types of vegetation, zonal aspects of relief and the characteristics of the hydrographic network, as well as by the forms of agriculturaluutilization. Photographs of zonality are to a great extent subject to seasonal changes. On the global photographs obtained from the artificial satellites of the Earth ATS-1, ATS-3, and ZOND-5, an asymmetry of zonality imagery was noted which was related to reverse changes in seasonal aspects of the northern and southern hemispheres. But even within the limits of a single hemisphere, at various seasons there are significant changes in the photographs of vegetation zones and in their boundaries. Thus, for example, in the spring, when the tundra is still covered with snow, the tundra is well differentiated from the forested zone and between the forested zone and the tundra there is a clearly evident transitional subzone of forest-tundra (Figures 1 and 2). In the late summer photographs this boundary was poorly distinguishable. The Savannas of the Sahelian Sahara in the wet seasons are depicted by a grey shade and merge in shade of photographs with typical savannas. At the dry time of year, on the other hand, they are depicted by a darkish-grey shade which is similar to that of the barren savannas. Below we shall cite the characteristics of the photographs of the basic latitudinal botanical-geographic zones of the northern hemisphere in the early summer aspect; these were obtained from the Tiros, Nimbus, Essay and Meteor artificial satellites of the Earth. During this process we shall not touch on photographs of clouds, whose distribution, although it also reflects latitudinal zonality (Arking, 1963), in a number of cases strongly masks the image of natural regions (particularly zones of tropical rain forests). /7

The Arctic zone is differentiated by its widespread light snow covering and glaciers. The Tundra zone is depicted by a low contrast combination of diffuse spots of an integral grey shade of the mossy tundras, by the somewhat greyer lichen covered tundra, and by the darker underbrush covered tundras. Many lakes are noticeable. The valleys of rivers are poorly pronounced, while certain of them can be traced by darker belts of meadow, forest and underbrush vegetation. The tops of bald mountains are covered with snow. The forest-tundra zone is characterized by sporadically distributed forests in areas supplied with water, which leads to the formation of a noticeable texture of dark grey spots in the areas between rivers and dark grey belts along the valleys of rivers.

The forest zone is recognized by the dark grey shade of forest masses which yield an abnormal spotty picture with a wrinkled texture, extremely contrasting, with the presence of lighter unforested territories: agricultural areas, swamps, flood plains, subalpine meadows, and bald mountains. The forested steppe zone is an even more contrasting combination of dark grey with a noticeable fine texture of forest masses and light grey homogenous unforested areas; the latter predominate.

The steppe zone is depicted by an even light grey, diffuse-spotted low contrast picture with noticeable dark belts of river valleys. The barren zone differs by an extremely heterogeneous large, abnormally spotted picture with contrasting dark grey belts of Hammada, and light grey belts – ergs with significant development in the remaining territories of a belted-lithogenic picture of the basic rocks and a dendritic-feathery picture of the dry channels (Wadi). The savanna zone differs from the preceding by an even grey shade with low contrast, diffuse picture and diffuse-belted boundaries, against a background of which darker spots of swampy lowlands and low hills are distinguished.

The zone of dry tropical forests is depicted by dark grey shade with a noticeable texture formed by the darker fragments of forest masses and somewhat lighter ones – nonforested territory covered by agriculturally worked areas or lightly forested regions covered by secondary and scattered forested vegetation. Finally, the zone of rain forests is set out by the darkest spot, on which one can weakly detect a homogeneous, abnormally spotty texture which is related to a change in composition of forests depending on relief and hydrography.

On space photographs the shape of the boundaries between zones and subzones of vegetation are depicted. Mosiac boundaries whose small spotted texture is well pronounced during the transition from tundra to forest and from forest to steppe zone. Diffuse boundaries are observed more seldom, from forest to steppe zone. Diffuse boundaries are observed more seldom, for example between barren and typical savannas.

Altitude belts of vegetation. The altitude belted nature of vegetation is recognized in space photographs on the scale $1:10^7$ and larger. The belted nature of vegetation is particularly well pronounced in mountains and in low mountainous, subarid regions. As an example we shall cite an analysis of the belted distribution of vegetations in the mountains of New Mexico, USA, where it has been studied quite adequately (Merriam, 1898; Meinzer, Hare, 1915; Shreve, 1922, 1942; Linney, Fabian, Hollinger, 1930; Duabenmire, 1943; Shields, 1956; Vegetative type, 1957). The belted nature of vegetation of the semidesert--forest type is represented in the mountains of Sacramento (Figure 3). /10

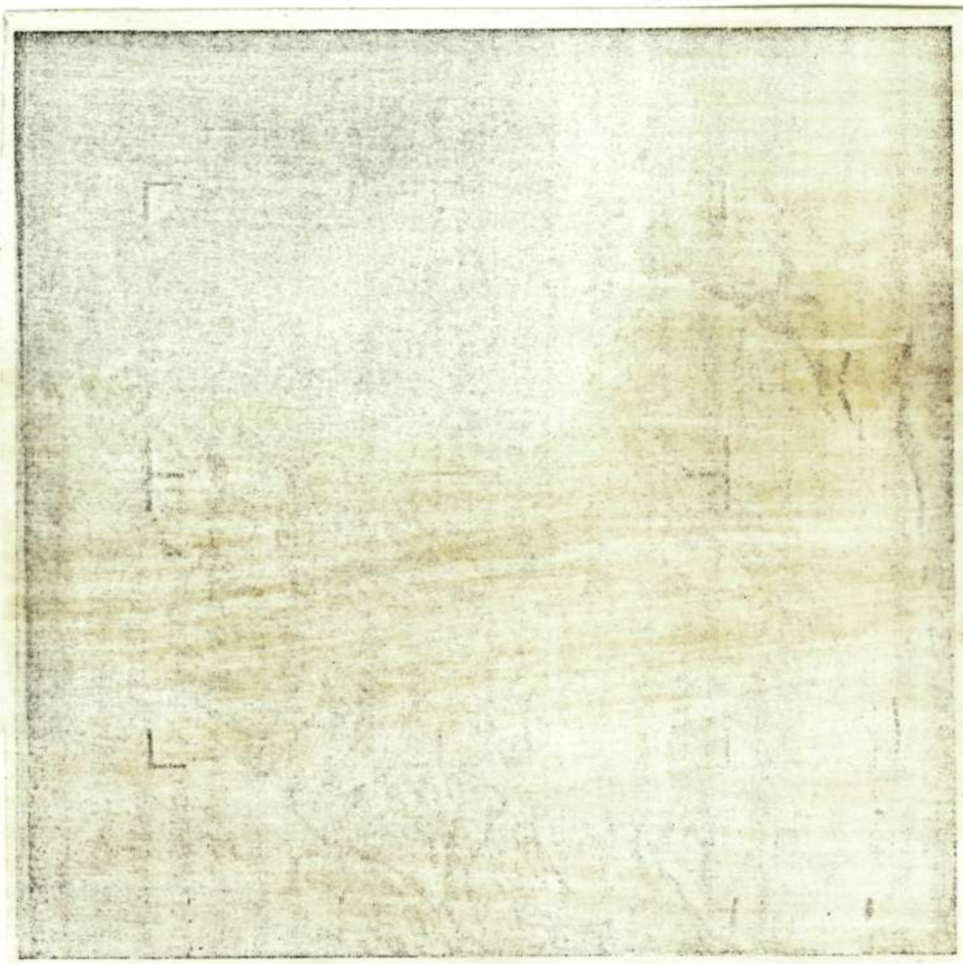

Figure 1. Television Image of the Northern European Part of the USSR and Western Siberia Taken from the ESSA-2 Artificial Satellite of the Earth on 21 March 1967. Scale nearly $1:15 \times 10^6$.

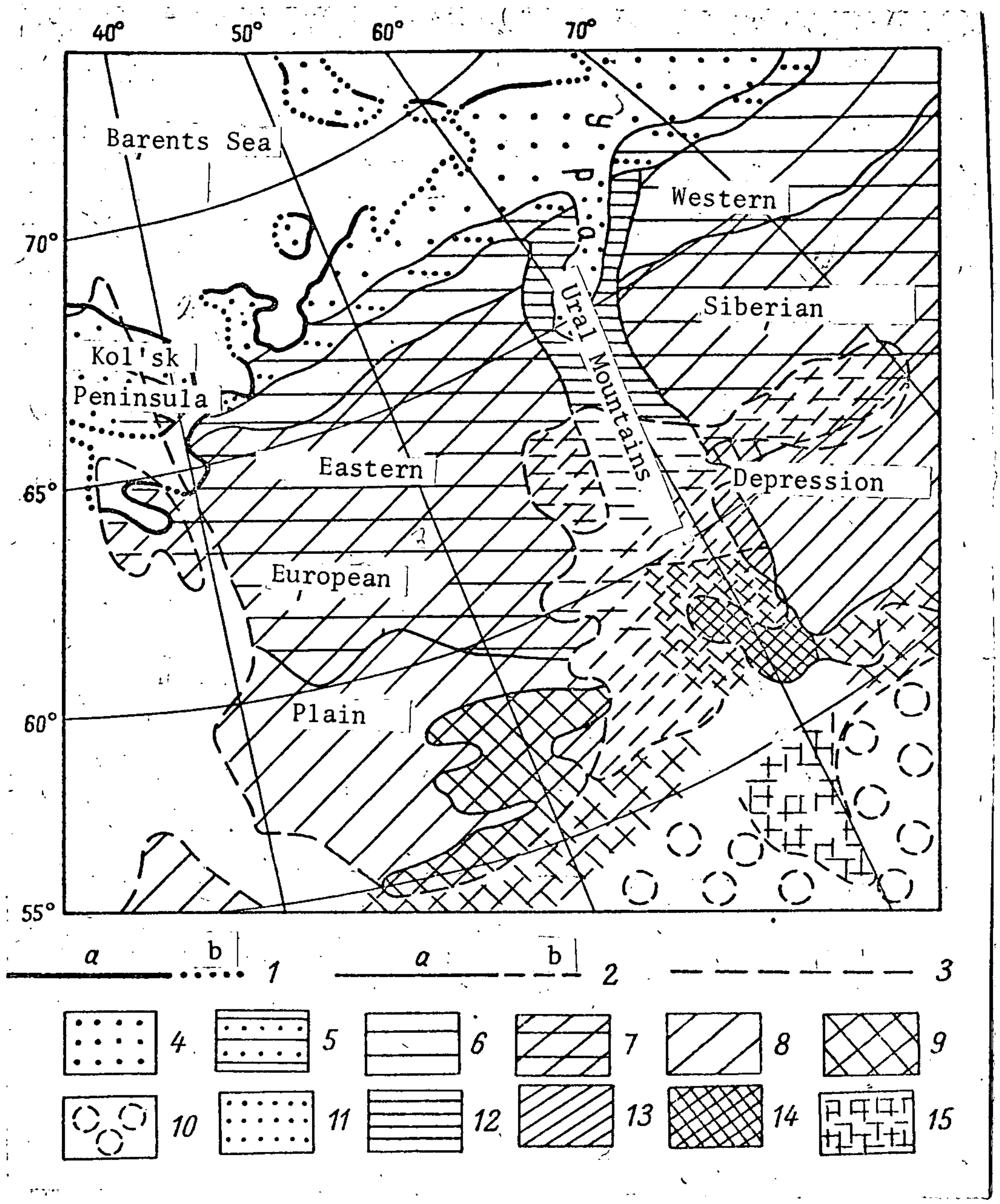

Figure 2. Zonal Makeup of Vegetation of the Northern European Part of the USSR and Western Siberia Interpreted According to Space Photography. 1, Shore line; a, recognized, b, interpreted; 2, boundaries of latitudinal zones and zonal types of vertical belts; a, probable, b, arbitrary; 3, boundaries of cloud cover. Territory having latitudinal zonality: 4, Arctic and typical tundra; 5, forest-tundra and pretundra thin forest; 6, Northern Taiga forest; 7, mid-Taiga forest; 8, Southern Taiga coniferus and mixed forests; 9, forest-steppe and deciduous forests; 10, steppes. Territories with zonal types of vertical belts: 11, mountainous tundra, alpine meadows and subalpine thin forests; 12, Northern Taiga mountainous forests; 13, mid-Taiga mountainous forests; 14, Southern Taiga mountainous forests; 15, forest-steppe and southern broadleaf-deciduous mountainous Taiga forests. Territories stretching along cloud covered regions and identified conditionally are shown by the shaded variants of the corresponding symbols.

The summits of the mountains of Sacramento at altitudes of more than 2,000 to 3,000 m above sea level are covered by thick pines (*Pinus ponderosa* Dougl., *P. lambertiana* Dougl.)- and fir (*Pseudotsutga douglasii* Carr.) forests. This altitude belt, in its ecological conditions, corresponds to the midCanadian zone known in the American literature (Merriam, 1898). The dense tree vegetation of this belt is depicted by a dense, dark, almost black shade masking the imagery of the relief. The lower Canadian zone occupies the slopes of mountains at the same altitudes. This is a park like somewhat steppe-like and thin forests of *Pinus ponderosa* Dougl., *P. jeffreyi* Balf. with a well developed grass covering comprised of species of the genera *Festuca* L., *Agropyrum* Roem. et Schult., and *Poa* L. On the unshaded slopes of mountains they are depicted as lighter, dark grey shades with noticeable expositional differences, and with a diffuse-spotted texture on lighted slopes and with light lines of nonforested channel bottoms (Figure 3). However, in view of the fact that under conditions of broken, mountainous relief comparatively small differences in composition and thickness of tree vegetation are masked by expositional differences in the illumination of slopes, the boundary between these belts is not shown by us on the map (Figure 4, 1) and they are joined into a single belt of the Canadian zone with pine and pine-fir forests.

The transitional zone at altitudes 1,800-2,200 m above sea level includes the lower belts of the slopes of mountains. The latter are covered by low (height 4-10 m) thin forests made up of pines (*Pinus edulis* Engelm., *P.monophylla* Torr. et Frem.), junipers (*Juniperus utaagensis* Lemm., *J. monosperma* Serg.), mahogany (*Swietenia mahagoni* Jacq.) and bushy oaks (*Quercus gambelii* Nutt., *Q. undulata* Torr. etc.) (in Spanish "savanetta"). The thin forest alternates with regions of dense undergrowth covering (made up of species of the genera *Bouteloua* Lag., *Stipa* L., *Agropyrum* Roem et Schult., *Poa* L.) and partial undergrowth types (*Artemisia* L., *Ceanothus* L., *Cercocarpus* H. B. K., *Purshia* Spreng.). In view of the thinness and low growth height, the tree-undergrowth community almost failed to yield its own image. The belt is depicted by contrasting shades which reflect deep erosional breakdown and strong expositional differences (Figure 4, 2).

The upper sonora zone occupies the bottoms of mountains and hilly foothills at altitudes 2,000 to 1,500 m above sea level. The vegetation of the zone consists of fragments of pine-juniper and, primarily, oak-mahogany thin forests and chapparals made up of oaks, mahoganies and underbrush (*Rhus trilobata* Nutt., *Purshia tridentata* DC, *Fallugia paradoxa* Engl., etc.), which form thick growths and which alternate with barren steppe-like open areas with (*Artemisia tridentata* Nutt.)-xerophil grasses (*Bouteloua eriopoda* Torr., *Hilaria mutica* Benth.) communities. The belt is decoded according to the contrast, small abnormal spotty picture of light grey spots of the eroded slopes with thin, semiscrub vegetation in illuminated expositions, and the grey — noneroded — slopes with thicker vegetation, as well as the dark grey — shaded slopes with thin forests and chapparals (Figure 4, 3).

The transitional Sonora zone is located on a foothill, sloping plain lower than 1,500 m above sea level and is made up of alluvial fans and wash--water plains. Vegetation consists of xerophil scrub (*Prosopis glandulosa* Torr., *Larrea tridentata* Coville, *Flourensia cernua* DC., *Rhus microphylla* Engelm., *Eurotia lanata* Moq.), species of wormwood and xerophilic grasses. The upper boundary of the belt is sharp, while the lower is diffuse. It is recognized according to the specific fan-like picture of foothill fans and plains (Figure 4, 4). The basic masses of arable soils are confined to this zone (Figure 4, 7).

The lower sonora zone at an altitude less than 1,200 m above sea level occupies the bottom of a foothill plain with saline, takyr-like soils and thalophyte scrub (of *Atriplex canescens* Nutt. and *Sarcobatus vermiculatus* Nees.) and grass (*Sporobolus airoides* Torr., *Allenrolfea occidentalis* Kuntze) vegetation. It is depicted by a uniform light grey shade with hard to detect grey spots of the depressions and also pronounced dark grey bands of the transit channels (Figure 4, 5).

Finally, on the bottom of the depression, the gypsum sands of White-Sands are located; a large part of this area is devoid of vegetation. Only on even regions and along the periphery of sand dunes does one encounter Psammo gypsophytes (*Oryzopsis hymenoides* Ricker, *Poliomintha incana* A. Grey, *Comandra pallida* A. DC., *Ephedra torreyana* S. Watts, *Rhus trilobata* Nutt., *Populus wislizeni* Serg.). The sands are well recognized according to their light shade with sharp boundaries and their more or less noticeable picture of aeolian dune-trench-like relief (Figure 4, 6).

Megacombinations of Plant Communities (the Vegetation of Regions). Most promising, to our view, is recognition of large territorial subdivisions of vegetation made according to space photographs and whose dimensions correspond to the size of the elementary geographic regions or to physical-geographic regions. For these goals, both original space photographs and television images can be used which are on the scale $1:10^6$-$1:5 \times 10^6$. Differentiation of megacombinations of vegetation is carried out according to differences in shade and picture of the photoimages, which are determined by the characteristics of vegetation, relief, geological structure, and agricultural utilization.

As an example we shall cite an analysis of the vegetation of regions of the Paris basin according to television imagery on the scale $1:2 \times 10^6$ obtained from Nimbus-1 (Figure 5). According to the character of the photographic images we designated 6 types of megacombinations of vegetation. Vegetation and conditions of the environment of the separated regions have been studied quite well (Jovet, 1949; de Martonne, 1950; Gaussen, 1953; Cholley, 1956; Rel, 1957; Bergen van den, Mullenders, 1957; Duviganud, Lucien, 1964; Beaujeu-Garnier, Bartie, 1967).

The vegetation of the region of the depression of the Paris basin (rivers Seine, Oise, and the damp region of Champagne) occupy the low, sloping surface with elevations 100 to 150 m above sea level, which is mildly broken by the channels of rivers and which is made up of Quaternary alluvial sands, marls, and sands of the paleogenic period. The yearly amount of precipitation is 500 to 600 mm — the least among all the other regions of the basin. A significant part of this area is covered by agricultural facilities on the low lying plains and by forests of oak, beech and chestnut on the slopes of hills. The region is depicted by dark winding belts of large rivers, the dark spots of forests and by uneven grey to light grey shades of the agricultural facilities (Figure 6, 1).

The vegetation of the region of the Brie, Bos and Valua plateaus. These are even, gently undulating plateaus with elevations ranging from 160 to 180 m above sea level and are made up of limestones and marls of the Paleogenic period covered with forest-like loams and broken by deeply cut river valleys. The amount of precipitation is not great — 500 to 600 mm. The plateaus are dry, with few rivers, and are almost entirely unforested, covered, to a large extent, by wheat fields. Vegetation is made up of waste lands and meadows on the plateaus with small masses of isolated oak forests on the slopes of hills and in valleys. The region is depicted by fields of an even light grey and very light grey shades, separated by extended isolated dark grey spots of forests along cuts, river valleys, and tectonic faults (Figure 6, 2). /12

Figure 3. Space Photography of the Mountains of Sacramento and the Valley of the Tularosa Obtained From the Aerobee Rocket. Scale of the foreground is nearly 1:4 X 10^5. /12

Plant cover of the region of chalky cut-layered plains of Dry Champagne. The plain is made up of weakly accumulated chalky rock impervious to water, frequently exposed on the surface. It is located at elevations of nearly 180 to 200 m above sea level and is broken by a slightly layered, cut relief with deep values of the transit rivers. The climate is relatively continental with 600 to 800 mm of precipitation. The plain is not very fertile and is thinly settled. Meadows sparsely covered by grass are characteristic for it with empty regions, agricultural facilities and small forest masses comprised of annual oaks and plantings of pines. This region is set apart by a lighter (light grey) integral shade among darker, forested territories cut through by narrow dark belts of transit river valleys. One notes a small contrasting, large "wrinkled" texture against a light grey background (Figure 6, 3).

Vegetation of the region of gently rolling seashore plains of Picardy. Plains with midly cut rivers in broad valleys composed of white chalk of the Cretaceous period and marls of the Paleogenic period are impervious to waters; they are covered with forest-like loams. They are located at elevations from 50 to 150 m above sea level. The climate is maritime with an increased amount of precipitation (700 to 1,000 mm). A large part of the plain is unforested and is covered with tillable soils, empty areas and meadows with the remnants of oak-white beech-beech forests. The picture of the region is distinguished in photographs by a most uniform shade with a low contrast fine texture and dark grey lines of river valleys (Figure 6, 4). /15

The vegetation of the regions of hilly elevations of Brey, the Marne, and Fer D'ot. The highlands are composed of frequently destratified marls, sands and limestones of the Paleogenic period. They are located on the heights more than 200 m above sea level and are broken by deeply cut river valleys. The amount of precipitation is slightly increased in comparison with the lowlands (up to 600-700 mm). In addition to agricultural facilities and meadows, significant areas are occupied by large masses of forests made up of annual and hellebore oaks and beech. The region is depicted by contrast combination of compact dark grey spots and light grey intermediate areas (Figure 6, 5).

The vegetation of regions of the cut-layered highlands of the Argonne, Cote-d'Mez, and Cote-d'Moselle. The cut strata are made up of dislocated subcretaceous and jurassic limestones, marls and sandstones. They reach 350-400 m and more above sea level, are asymmetrical, and are cut by broad, successive river valleys. The climate is a moderate continental one with an increased amount of precipitation (up to 800-1,000 and in places 1,200 mm). Vegetation consists of thick forests of oak, white beech and beech in the highlands, meadows and agricultural crops in the intermountain valleys. The region is well depicted in the longitudinal orientation by dark to dark grey spots of forests separated by grey bands of valleys (Figure 6, 6).

The vegetation of the region of moderately high mountains at the Ardenne and Vogez. These are mountains of Hercynian orogenosis and are made up of mesozoic and paleozoic metamorphic rocks, schists and sandstones. The altitude of the mountains are 500 to 550 m above sea level. The amount of precipitation is greatest within the limits of the Paris basin — 800 to 1,200 mm. Vegetation us made up of dense forests of beech, oak, white beech, spruce and birch. The region of mountains is set apart by large dark masses cut through in places and by dark grey spots with extended outlines (Figure 6, 7).

In the semiarid conditions vegetation of the regions is recognized either geobotanically or according to the geological-geomorphological signs. This is observed during an analysis of the vegetation of regional belts of the mountains of Sacramento and the Tularosa valley (see above). The photographic images of the regions of the Canadian zone are determined by the vegetation and by relief, which are also basic decoding signs. The regions of the lower belts of the Sonora zone, in view of the broken nature of vegetation, are interpreted according to the geological-geomorphological signs: hilly relief of the foothills, alluvial fans, colluvial plains, the submountainous, argillaceous plain and sandy masses.

Under arid conditions, the characteristics of the photographic image of the region are determined by their exclusively or nearly exclusively by the lithologic and geomorphological factors. However, on the strength of a certain influence of ecological conditions on the formation of vegetation, identification /17 of the latter according to geological and geomorphological signs is entirely efficient.

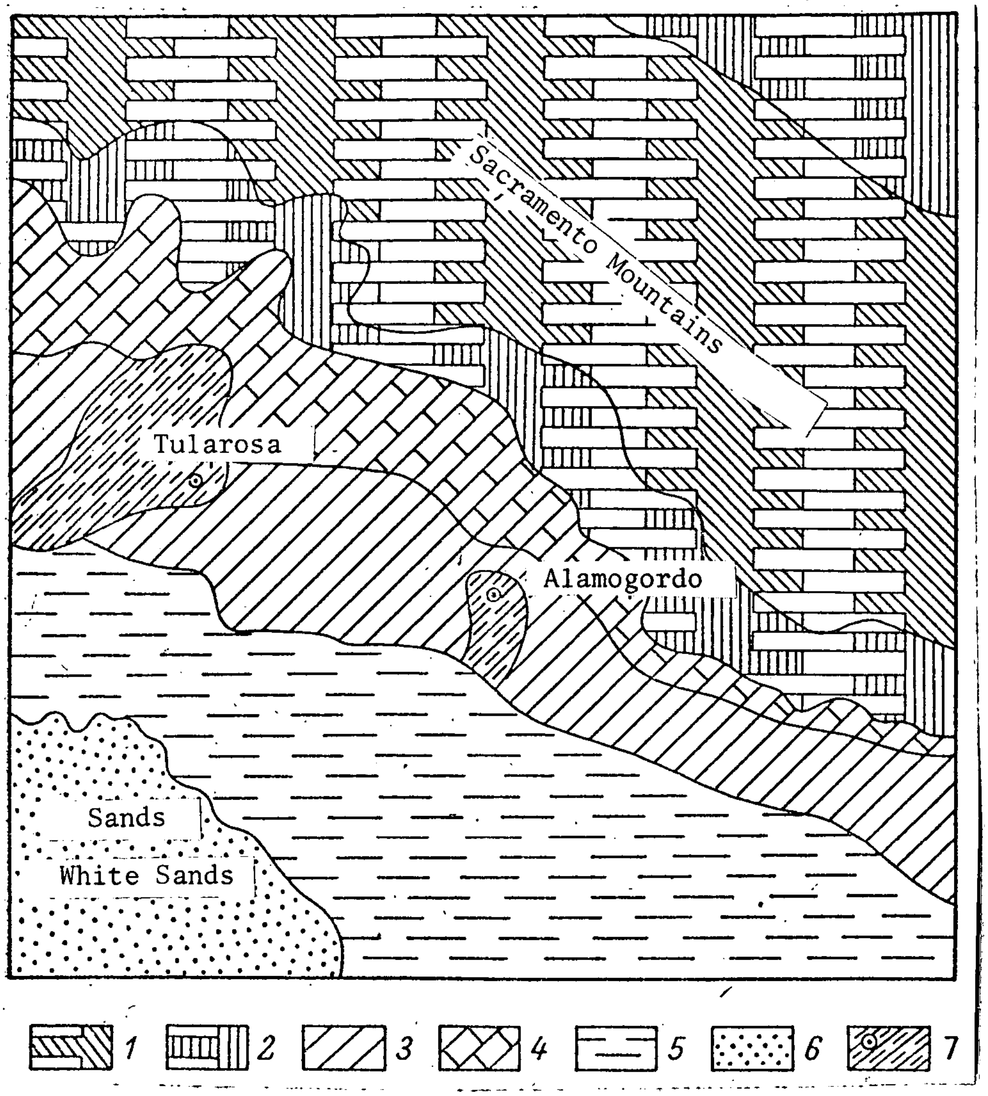

Figure 4. Belted Nature of Vegetation of the Sacramento Mountains and the Tularosa Valley Interpreted According to Space Photography. 1, Pine and pine-fir forests of the tops and top parts of mountainous slopes of the Canadian zone; 2, pine, juniper, mahogany and oak thin forests on the slopes of mountains of the transitional zone; 3, thin forest and wormwood-xerophilic, grassy semiarid regions of alluvial fans and colluvial plains of the transitional Sonora zone; 5, halophilic scrub land of the submountainous plain of the lower Sonora zone; 6, the sands of White Sands with pioneer psammophytic (and gypsophytic) vegetation; 7, arable land. /13

/14

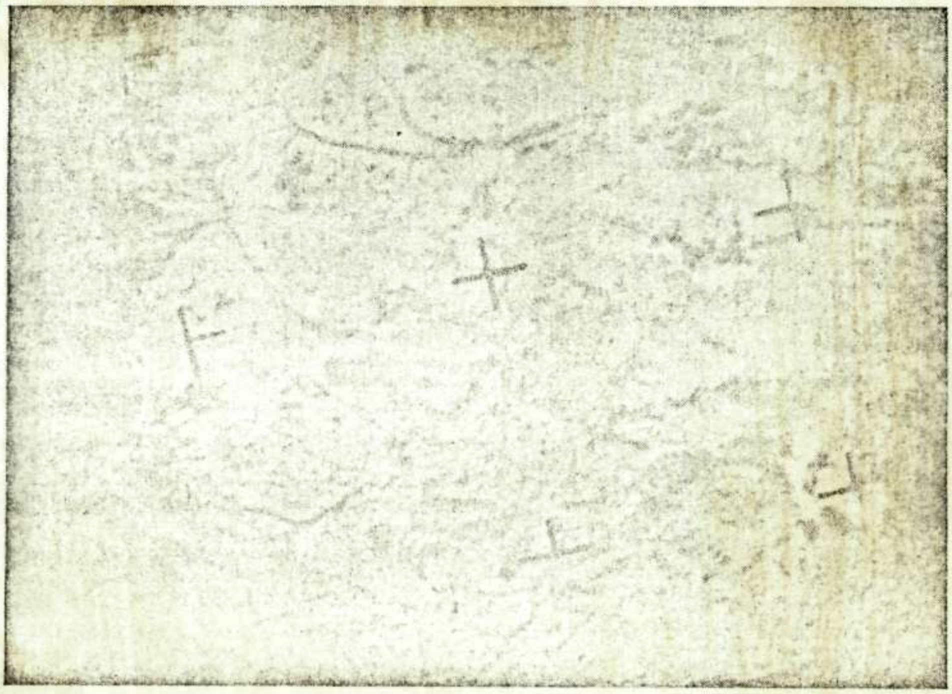

Figure 5. Television Image of the Paris Basin Taken from the Nimbus-1 Artificial Satellite of the Earth in September 1964. Scale approximately $1:2 \times 10^6$.

Photointerpretation of Typological Categories of Vegetation. More detailed interpretation of vegetation according to space photography on the scale $1:10^6$ and larger is an extremely complex problem. It includes recognition of both taxonomic units of vegetation: formation, groups of formations, classes and groups of associations, and also territorial units: vegetation of locales and areas. Its solution is based upon the development of decoding signs of formations. However, problems of decoding vegetative communities according to space photography have remained nearly undeveloped. Standards have not been worked out and the principles of optical and geometric generalizations are not determined. Nevertheless, recognition in space photography of the outlines of geobotanic maps have allowed us to come to some conclusions concerning the character of super small scale photographic imagery of vegetation (Vinogradov, 1969).

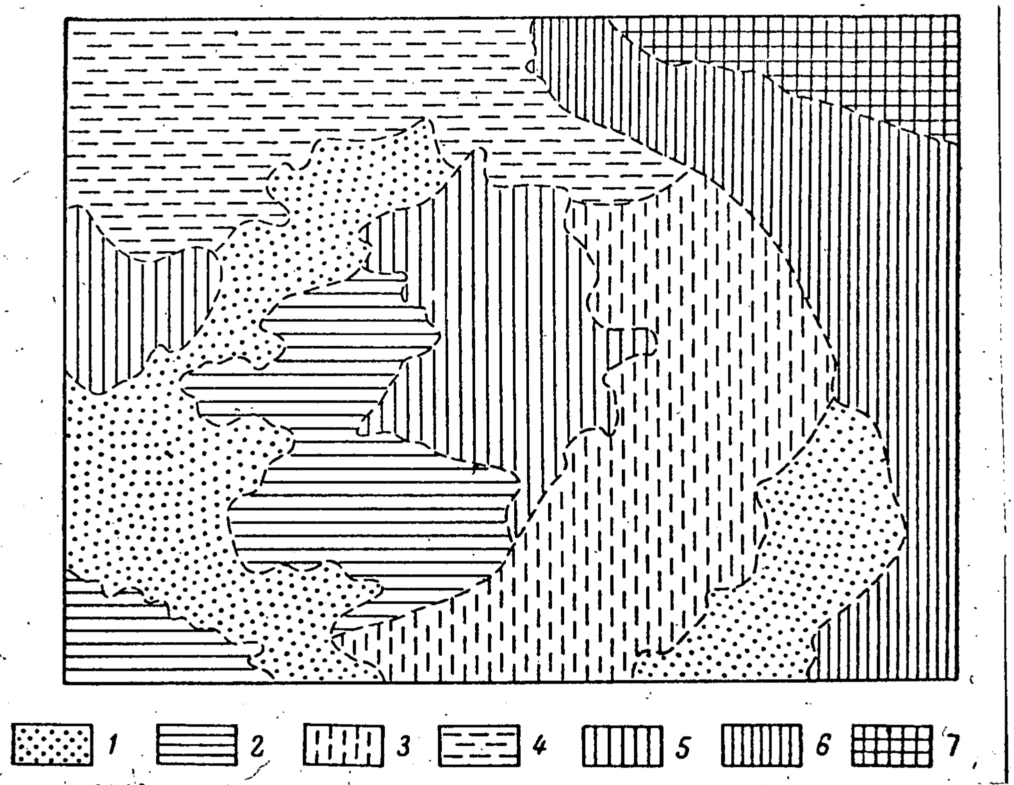

Figure 6. Vegetation of the Regions of the Paris Basin Interpreted According to Space Photography. 1, Combination of agricultural crops and forests consisting of oak, beech and chestnut in the alluvial lowlands; 2, combination of barren regions and meadows on the even, chalky plateau and oak and oak-chestnut forests on the slopes of the plateaus and in the valleys; 3, combination of barren regions, meadows, agricultural crops and small scale forests of annual oak and planted pines on a cut-stratified chalky plains; 4, combination of agricultural crops, barren areas, meadows and isolated oak-beech--oak forests on the rolling maritime plain; 5, combination of forests consisting of evergreen and annual oak, beech, meadows and agricultural crops of the hilly highlands; 6, combination of forests of oak, beech and white beech, meadows, and agricultural crops on the cut-stratified highland; 7, combination of forests consisting of chestnut, beech, oak and also spruce and birch in the moderately high mountains.

As an example of identification in space photography of the outlines of small scale formation of a map, we shall cite the results for identifying vegetation of the Paris basin (Figure 7) on photographs obtained from the Nimbus-1 artificial satellite of the Earth (Figure 5).

In the space photograph the darkest, almost black shade depicts the chestnut-oak forests (consisting of *Quercus pedunculata* Ehrh., *Fagus silvatica* L.) with an admixture of spruce and birch (*Picea decidua* Mill., *Betula pubescens* Ehrh.) in the Ardenne. Somewhat less dense, but also dark, and dark grey, and also having an even shade with a diffuse boundary is the manner in which the large masses of oak-chestnut forests with beech are set apart (*Carpinus betulus* L.) in Oise, the Ardenne, and Argonne. The same shade depicts the masses of chestnut (*Castanea sativa* Mill.)-oak forests of the Seine lowlands. In similarity of image they, in differentiation from the beech-oak forests, are confined to various geographic regions. The masses of beech-oak forests are somewhat less dense and the light forests of the Marne, Oise, the Ardenne and the Argonne are recognized by their dark-grey shade with infrequent cloud-spotty texture. The forest consisting of annual oak (*Quercus pubescens* Willd.), and plantings of pine alternate with empty areas, fields, and vineyards of Dry Champagne. The annual oak is characterized by a more uniform yellowing of its leaves, while in the autumn aspect its groves differ from those of the winter oak by a lighter shade. These locales are depicted by a subintegral light grey shade with a larger and more contrasting cloudy-spotty "wrinkled" texture. The river valleys with flood plains and swampy forests are composed of ash, willows, alders, and poplars with meadows, occasional small marshes, gardens, and flower gardens depicted by narrow dark grey belts with extremely sharply defined boundaries. The flood plain vegetation is well decoded if it has a width greater than 0.5 km and is located among unforested or thinly forested territory, but is masked in the midst of dark grey watery areas of oak-beech, white beech forests.

The dimensions of forest masses to a significant extent influence the formation of the shade of imagery in space photographs. Thus, small masses of /18 forests (less than 2-4 km) with the same composition of rock form a lighter (grey) shade than large forests (4-10 km and larger), which are set apart by a dark grey or dark shade. Small forested regions (less than 1-2 km) which are too small in size, and sporadically distributed alternate with agricultural crops, meadows and empty spaces and yield subintegral images, i.e., separate regions of forests, although they do yield a mildly pronounced separate image, cannot be graphically sufficient for accurate shape and measurements. Similar shapes are recognized according to low contrast; fine diffuse-spotty texture and the forests in them stand out in the form of combinations (locales and groups of bounded areas) together with other types of arable areas. Forests encountered in small, grovelike masses (splits) yield a shade of subintegral imagery of intermediate intensity between light grey unforested and dark forested territories. Thus, with a forested area containing 30 to 50% trees (oak--beech forests), the outlines yield a subintegral image of a grey shade with a well defined diffuse-spotty texture corresponding to the fragmentary structure of the vegetation.

More or less even light grey and grey shades form the image of unforested lands with meadows (natural and cultivated), barren areas, plowed ground, and vineyards in Picardy, and along the edge of Dry Champagne, on the Brie plateau and in the Seine lowlands.

The detailed nature of detecting vegetation shown on the map having a comparable scale (Gaussen, 1953) turned out to be extremely high. In the photograph we obtained a clear differentiated imagery of almost all regions of forest having dimensions greater than 2 to 4 km which were shown on the map. Only the wet, meadow-bog lowlands of the river Ser (Ena) and the rivers Marne, She or Orne (Wet Champagne) or in places similar to the image of forests (but differ in configuration of outlines). Forest masses are differentiated according to basic forest-like soils with a probability of 0.7 (with a permissible margin of inaccuracy of 10%). When one cannot separate soil according to the shade of the image one can use the data of zoning. Thus, the beech-oak forest of the Marne and the Argonne have the same dark grey shade as the chestnut-oak forest of the Seine, but they differ in their belonging to various physical-geographic regions (see Figures 6 and 7). Zoning increases the probability of recognition to 0.9 with the same margin for error.

Conclusion

Experience in interpreting space photography is extremely limited. However the obtained preliminary data demonstrate that space photography can be used for territorial integration of large phyto-geographic units, such as latitudinal zones, vertical belts, geobotanical regions, mega- and macrocombinations. During this process, in view of factor integration, phyto-geographic units found by space photography correspond well to the units of regional differentiation.

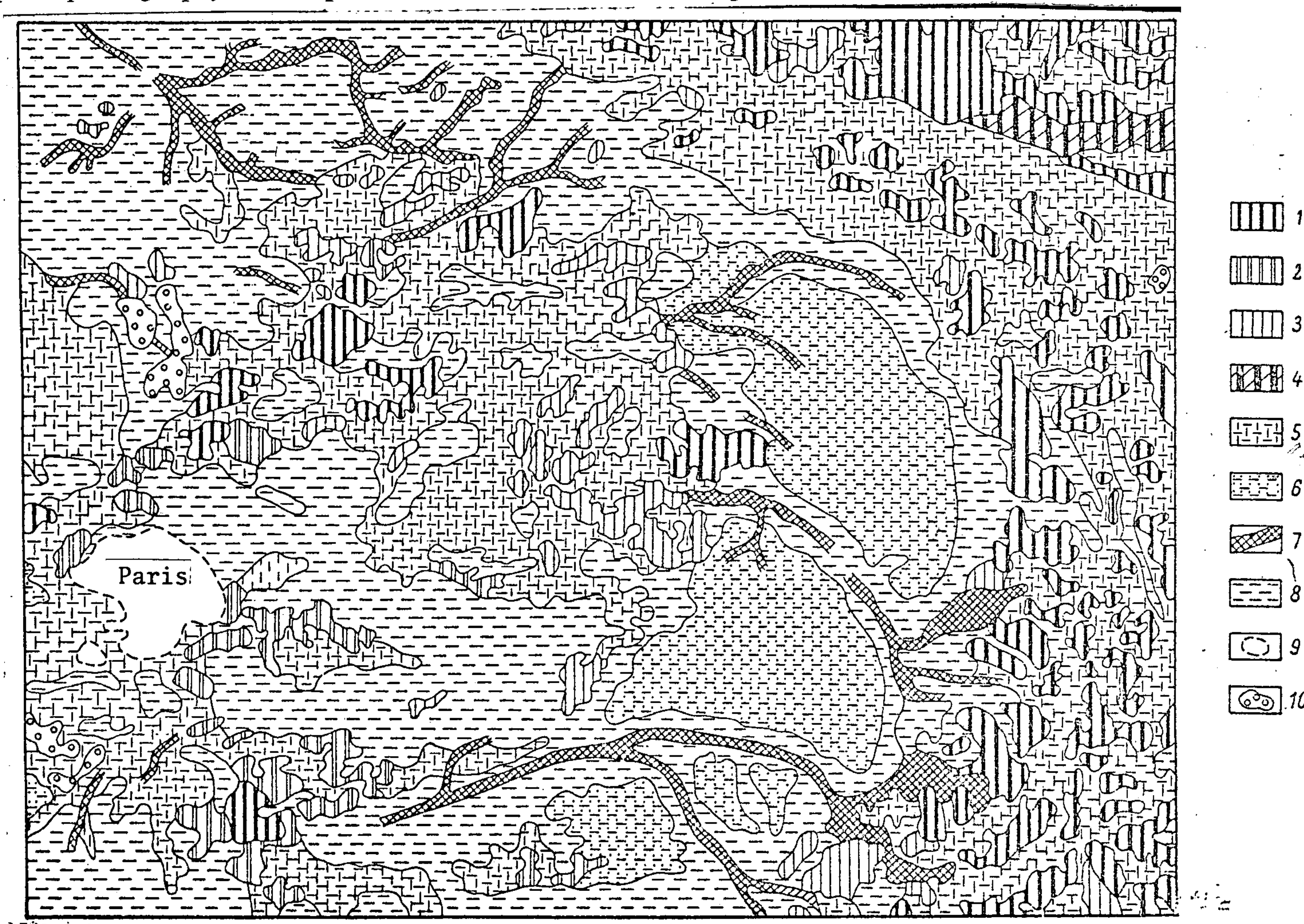

Figure 7. Map of the Vegetation of the Paris Basin Marked Out On a Television Image. 1, Beech-white beech-winter oak forests; 2, chestnut-mixed oak forest; 3, mixed oak forest; 4, oak-winter oak forest with an admixture of spruce and birch; 5, combination mixed oak forest with meadows, and agricultural crops; 6, combination of summer oak forests, plantings of pines with meadows, barren areas and agricultural crops; 7, combination of flood plains and lowland poplar, ash, alder, and willow forests and brush covered land with natural and cultivated meadows, grassy bogs and agricultural crops; agricultural crops, natural and cultivated meadows, occasionally barren stretches; 9, area of urban structures, territories devoid of natural vegetation; 10, small cloud cover masking the vegetation image.

REFERENCES

Arking, A., "Latitudinal Distribution of Cloud Cover from Tiros III Photographs," *Science*, Vol. 143, No. 3606, 1963.

Badgley, P. C. and W. L. Vest, 1966.

Vinogradov, B. V., "Space Photography for a Geographic Study of the Earth," *Izv. Vses geogr. obshch.*, Vol. 98, No. 2, 1966a.

Vinogradov, B. V., *Aero- metody izucheniya rastitel'nosti aridnykh zon* [Aerial Methods of Studying the Vegetation of Arid Zones], Moscow-Leningrad, 1966b.

Vinogradov, B. V., "Complex Interpretation of Photographs of the Earth Obtained from Nimbus-1," *Izv. vses geogr. obshch.*, Vol. 101, No. 3, 1969.

Vinogradov, B. V., K. Ya. Kondrat'yev and D. V. Stepanenko, "Possibilities for Interpreting Photographs of the Earth taken from Space and Observed in Various Zones of the Spectrum," *Kosmicheskiye issledovaniya*, Vol. 6, No. 6, 1968.